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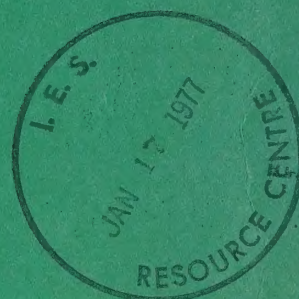
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WASTEWATER AND SLUDGE CONTROL IN THE CANADIAN METAL
FINISHING INDUSTRY, 1976.

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Wastewater and Sludge Control in the Canadian Metal Finishing Industry



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Report EPS 3-WP-76-10

—Water Pollution Control Directorate
December 1976

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WASTEWATER AND SLUDGE CONTROL IN THE
CANADIAN METAL FINISHING INDUSTRY

Segment including chemical, electrolytic treatment;
electrochemical machining and polishing; cyanide hardening

by

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ABSTRACT

This report describes technical and economic aspects of the development, under the Fisheries Act, of national effluent requirements for the segment of the Canadian metal finishing industry which includes chemical and electrolytic finishing of surfaces and cyanide hardening. Recommendations for the control of effluents are presented, based on the best practicable technology and economic considerations.

RÉSUMÉ

Ce rapport traite de l'élaboration, aux fins de la Loi sur les pêcheries, de normes nationales touchant les effluents de l'industrie de finition des métaux. Il en considère les aspects tant économiques que techniques. Il convient de rappeler que cette industrie fait appel à des procédés chimiques et électrolytiques ainsi qu'à la trempe en bain de cyanure. Le rapport recommande de traiter les effluents selon les meilleures méthodes connues, qui soient praticables compte tenu des facteurs économiques.

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CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. There are more than 7,000 plants in Canada that can be broadly defined as metal finishing operations.
2. As a first stage in the development of effluent control requirements, only a segment of the metal finishing industry is under consideration. This segment includes plants primarily engaged in such operations as chemical and electrochemical finishing of surfaces, cyanide hardening, and electrochemical machining and polishing.
3. Wastewaters from these operations contain heavy metals, cyanides and other inorganic and organic substances. These constituents enter the effluent stream mainly through dumps, spillages and leaks, and rinse water.
4. Dumps result from the disposal of spent solutions and sludges generated by the normal operation of a metal finishing plant. They may contain up to 200,000 milligrams per litre of contaminants.
5. Dumping is usually an off-shift operation. Where regeneration is not practical, dumps can be segregated and treated or sent to a disposal facility.
6. Spillages and leaks resulting from overflows, accidents, etc. can be contained and recycled, treated, or sent to a disposal facility.
7. It is estimated that approximately 70% of the chemicals consumed by the industry is lost through dumps, spillages and leaks.
8. Rinse water contains the balance of chemicals and up to 8% of the metal anodes consumed. It is normally discharged with the plant effluent. Concentrations of metal ions in untreated effluents can range from less than 1 mg/l to more than 100 mg/l.
9. Chemicals and metal ions in wastewater can be removed by various techniques, e.g. ion exchange, evaporation, reverse osmosis, etc. However, none of these is applicable in all cases, because of technical or economic considerations.

10. Chemical treatment appears to be the only technology applicable to all metal finishing effluents. The following steps can be considered part of Best Practicable Technology (BPT) for the development of control requirements: segregation and destruction of oxidizable cyanide; segregation and reduction of hexavalent chromium; precipitation of metals; settling, separation and disposal of sludges.
11. After the application of BPT, metals and other contaminants in the final effluent are expected to be in the order of fractions of milligrams per litre.
12. Chemical treatment lends itself to the application of additional methods or steps to further improve the quality of the effluent prior to discharge.
13. Spent baths and sludges are generated by the normal operation of a metal finishing plant and they must be disposed of.
14. Where feasible, centralized treatment facilities appear to be the best solution for disposing of spent baths and sludges. The alternative to common facilities is treatment, dewatering and disposal by each individual company, unless deep well disposal is feasible and permitted.
15. Approximately two-thirds of the metal finishing plants in Canada discharge into municipal sewers. However, considering the number of existing municipal treatment plants and their effectiveness, many such discharges are in fact indirect discharges to receiving waters.
16. Discharges to municipal sewers can be regulated under the Fisheries Act.
17. Most municipal treatment plants are not designed to removal metals or other contaminants to the same extent as BPT. However, a certain amount of treatment takes place, depending upon the characteristics of the effluent and the unique technological capabilities of the municipal treatment plant.

18. Companies could be required to provide evidence of any off-site treatment received by their effluent and to provide complementary effluent treatment to ensure equivalence with BPT.
19. Uniform control requirements for discharge to municipal sewers are necessary to prevent the establishment of new plants in locations where, because of less stringent bylaws or loose enforcement, substantial capital investment and operating expenses can be deferred or avoided.
20. In general, the cost of applying BPT is estimated to be from \$15,000 to \$100,000 or more per plant, depending upon size and complexity.
21. Operating costs are estimated to be from \$9,000 to \$75,000 per year, depending upon size and complexity.
22. For small plants (up to \$200,000 annual sales), capital cost is estimated to be between \$15,000 and \$40,000, and operating costs between \$9,000 and \$30,000 per year.
23. From the point of view of initial investment it is estimated that the application of BPT will require from 20 to 40 percent additional capital, depending upon size and complexity. Smaller plants will require much more.
24. It is estimated that a capital investment of 15 to 17 million dollars may be needed, in addition to equipment already in place, to apply BPT to this segment of the metal finishing industry.
25. The operating costs are estimated to be between 10 and 13 million dollars per year.
26. To apply BPT, there may be additional costs to be borne by each plant, such as the cost of land and building, which may range from \$4,000 to \$30,000.
27. Dewatering of sludges may add approximately \$10,000 to the cost per plant; the disposal cost will vary with the volume.
28. Metal finishing effluent requirements should consist of a combination of regulations, guidelines and code of practice. They should

explicitly prohibit the dumping of sludges and concentrated solutions, request the application of good housekeeping procedures to contain spillages and leaks, and limit the maximum concentration of each control parameter in the effluent.

29. The application of the above controls may not produce a non-toxic effluent. However, such controls will very significantly reduce the pollution load from the metal finishing industry.
30. The promulgation, today, of effluent regulations will create a situation where sludges and concentrated solutions cannot be discharged to receiving waters. In the majority of cases, satisfactory disposal will also not be possible because adequate facilities do not exist.
31. Practicable sludge treatment and disposal technology is available abroad.

Recommendations

1. Effluent control requirements should be developed for the metal finishing industry. A first step should be to control the segment including chemical and electrochemical finishing of surfaces, electrochemical machining and polishing, and cyanide hardening.
2. In order to ensure equity in control requirements, discharges of metal finishing waste to receiving waters or to municipal sewers should be limited under the Fisheries Act.
3. Control requirements should:
 - a) prohibit dumping practices;
 - b) encourage containment of spillages and leaks; and,
 - c) limit the concentration of control parameters in the final effluent.
4. Special provisions should be incorporated in the requirements to exempt effluents if treated in facilities outside the plant, such as a municipal sewage system or a central treatment facility. The exemption should be given where the off-site treatment facility provides treatment equivalent to that of the control requirements.

5. Control requirements should be expressed as objectives for a limited period of time in order to allow municipalities and provinces to organize adequate sludge impoundment facilities.
6. The establishment of centralized treatment facilities for sludges and concentrated solutions should be strongly encouraged by the federal government.

1. INTRODUCTION

This report is intended to highlight the different aspects of the development, under the Fisheries Act, of national effluent requirements for the segment of the Canadian metal finishing industry which includes chemical and electrolytic finishing of surfaces, cyanide hardening, and electrochemical machining and polishing.

The report has been prepared taking into consideration the discussions held within the Federal-Provincial-Industrial Task Force responsible for recommending effluent requirements for this industry. The conclusions expressed are based upon practical experience, and extensive consultations with knowledgeable representatives of the industry and regulating agencies in Canada and abroad.

Effluent control requirements, as recommended in the report, will result in a considerable reduction of waste discharged to receiving waters by the metal finishing industry.

2. TECHNICAL ASPECTS OF WASTEWATER CONTROL

2.1 The Metal Finishing Industry

A broad definition of metal finishing is "the application of a mechanical, physical, chemical or electrochemical operation to a metal substrate to change its physical characteristics". This also applies to the application of a metallic coating to non-metallic surfaces.

The major processes within the definition include cleaning, polishing and grinding, galvanizing, painting, phosphating, chromating, cyanide hardening, anodizing, and electroplating. These can be found alone or in various combinations in more than 7,000 plants in Canada, mostly as captive operations (i.e. part of a larger operation).

As a first stage, effluent control requirements were considered for that segment of the industry primarily engaged in operations such as chemical (chromating, electroless plating, bright dipping) and electrolytic finishing of surfaces, cyanide hardening, electrochemical machining and polishing. Excluded were other chemical processes, as defined in the survey [1], and plants primarily engaged in operations such as physical or non-metallic coating.

From the available information, the size and geographical distribution and other relevant data for plants within this segment have been tabulated in Table 1. Sales indicated are based on an extrapolation from the number of employees and the consumption of metal in the metal finishing operations.

From the national survey [1] and practical experience, it is estimated that, in terms of volume, over 80% of the industry is in Ontario and over 30% of that is in the city of Toronto. The largest section of this industry serves the automotive industry. Seven Ontario companies supplying this industry account for 40% of the total activity for the entire Canadian metal finishing industry. The percentage in terms of number of companies appears different, with approximately 65% located in Ontario.

Quebec is estimated to have 15% of the volume, with 20% of the companies.

TABLE 1. METAL FINISHING INDUSTRY SIZE AND GEOGRAPHICAL DISTRIBUTION - 1973
(segment under consideration)

	No. of Companies		No. of Employees		Investment	Sales
Atlantic Provinces	3 ¹	4 ²	10 ¹	20 ²	250,000 ^{2,3}	350,000 ²
Quebec	40	55	600	1,300	10,000,000	21,000,000
Ontario	159	216	4,150	5,400	60,000,000	130,000,000
Manitoba, Saskatchewan and Alberta	21	30	250	370	3,000,000	6,000,000
British Columbia	25	25	240	240	2,000,000	4,000,000
Total Canada	248	330	5,250	7,330	75,250,000	161,350,000
Urban ⁴ - Quebec	-	51	-	1,175	9,000,000	19,000,000
Urban ⁴ - Ontario	-	186	-	4,360	50,000,000	110,000,000
Rural - Quebec	-	4	-	125	1,000,000	2,000,000
Rural - Ontario	-	30	-	1,040	10,000,000	20,000,000

¹Actual Survey figures

²Estimated Total

³Estimated replacement value (in 1973)

⁴Greater than 25,000 population

2.2 Effluent Sources and Other Contaminants

The effluent from this industry contains acids, alkalis, suspended solids, heavy metals, cyanide, phosphates, some oil and grease and, in minor quantities, a variety of other organic and inorganic chemicals. These substances enter the effluent stream mainly through dumps, both deliberate and accidental; accidental spillages; leaks; floor wash; and, by way of the running rinses that wash the work between processes.

Dumps result from the necessary discharge of spent baths, such as alkaline cleaners, acids, chromates, and sludges from filter cleanouts, barrel operations and purification procedures. Accidental spillages such as overflows, tank and filter leaks, and spills between processes also enter the effluents. The concentrations in these dumps and spillages may vary from 200,000 or more mg/l for chromic acid to 500 to 1,000 mg/l for metal in nitric and sulphuric acid solutions used for bright dipping of these metals.

Since dumps mostly occur off-shift there is a minimum of control in most installations in the handling of their disposal when there is no treatment system.

It is estimated that dumps, spillages, leaks, etc. may account for up to 70% of the chemicals consumed by the industry, the balance being lost through the rinses. While the percentage may vary from process to process, its accuracy is supported by the experience of many Canadian metal finishers.

Where only running rinses are discharged, the untreated effluent will contain metal ions in concentrations from less than 1 mg/l to more than 100 mg/l [1]. The variation is accounted for by relative quantities in the individual processes used, the nature of the process and the production techniques of the operator. The latter is by far the largest variable.

The quantities of substances reaching the effluent stream in rinse water are influenced by drainage time, drag-out recovery systems; and the design and condition of fixtures. If no limits are placed on effluent contaminants, the only incentive to prevent losses to rinse water is the cost of replacement chemicals. In most instances, this

is regarded as less important to the operator than the reduction in production that may be required to save chemicals.

Chemical losses are periodically replaced and Table 2 shows some of the chemicals consumed by metal finishers in Canada.

TABLE 2. CONSUMPTION OF CHEMICALS BY THE METAL FINISHING INDUSTRY [1]

Cadmium compounds (including cyanides)	25,600	lb/yr
Copper compounds (including cyanides)	445,000	lb/yr
HCl, H ₂ SO ₄ and other acids	22,169,000	lb/yr
Chromic acid, miscellaneous chromates	1,719,000	lb/yr
Phosphoric acid and miscellaneous phosphates	4,703,000	lb/yr
Nickel compounds	1,253,000	lb/yr
Caustic soda	2,533,000	lb/yr
Other cyanides	1,161,000	lb/yr
Detergents	2,164,000	lb/yr
Chlorinated hydrocarbons	5,600,000	lb/yr
Alkali cleaners	610,000	lb/yr

Another source of contaminants in the effluents is represented by metal ions from the dissolution of metallic anodes. It is estimated that, in addition to chemical losses, up to 8% of the anodes consumption could be lost to wastewater through the rinses. This is true when no recovery techniques are applied.

Table 3 shows the consumption of some metal anodes by electrolytic processes in Canada.

TABLE 3. CONSUMPTION OF METAL ANODES BY ELECTROLYTIC PROCESSES [1]

Cadmium	approx.	132,000	lb/yr
Copper	"	313,000	lb/yr
Nickel	"	5,984,000	lb/yr
Tin	"	44,000	lb/yr
Zinc	"	684,000	lb/yr

There is a wide disparity in appreciation and control of these losses by the industry. Even some quite large companies have excessive losses. The survey of the metal finishing industry [1] and practical experience confirm this variance.

2.3 Prevention of Losses

In spite of the obvious cost factors in chemical losses, a large part of the industry is not aware of how much they could be reduced by use of better techniques. The increase in the cost of chemicals is now bringing some of these factors to their attention more forcibly and more metal finishers are reacting positively to the prevention of losses.

The avenues that are available include:

Substitution - The replacement of process chemicals containing deleterious substances with others that are harmless or much less harmful, e.g. use of cyanide free or low cyanide plating baths.

Water use - Substantial reduction in water flows is possible through improved rinsing techniques, as well as through the use of chemical rinsing in a closed loop system.

Control of accidental spillages and leaks - Much prevention could be provided by manifolding rinses, sealing floor drains, using spring loaded valves for water make-up, sealing or removing valves on the bottom of tanks, using siphon breakers and making periodic maintenance checks of tanks and filters.

Drag-out and drainage - Automatic machines can be designed to minimize drag-out and maximize drainage. This design costs a little more but much new equipment is being installed without these features.

Reclaim - The simplest of all recovery methods, often omitted because of space limitations, it requires only a still rinse tank after a process tank.

Regeneration - Many process baths can be regenerated when contaminated.

Solution concentration - With care, process solutions can be operated at their lowest possible concentration, thus reducing drag-out.

The common denominator in all of these procedures, or lack of them, is the quality of the supervision and management. Most, but not all, the larger plants follow these procedures. Most of the rest follow only a few of them.

2.4 Wastewater Control

While chemical losses can be decreased by preventative measures, there will still be spent baths and sludges to be disposed of, as well as spillages, leaks, etc. However, these can be prevented from entering the final effluent by segregation, containment, batch treatment and/or shipment to an off-site disposal facility.

Metal ions and chemicals present in the rinses may be removed by recovering them before they reach the wastewater, or by treating the effluent itself before discharge.

These are the different recovery techniques available:

Chemical recovery - One Canadian company is precipitating nickel as the carbonate in a chemical rinse system and exchanging it for nickel sulphate. Larger plants in England, and central treatment facilities in Germany, have been able to market some of the metal hydroxides removed from wastewater. In Canada there is no known market for such metal hydroxides. Examples of capital costs of recovery are shown in Appendix 1.

Ion exchange - There are several ion exchange installations in Canada, mostly used for the recovery of nickel and chromium. Evaporation is often necessary to concentrate the solution recovered. Metal impurities may accumulate and limit the use of this technique. A by-product of the use of ion exchange is high quality rinse water. The presence of cyanide is a limiting factor in the use of ion exchange.

Evaporators - This recovery method has been in use for several years in Canada in the largest plating plants, mainly on chromic acid baths. Closed loop systems are possible, permitting the condensate to return to the rinse tanks and the chromic acid to the plating bath. There are two or three evaporators operating on nickel baths in Canada and it is also possible to recover cyanides, but there are no installations in Canada. The use of evaporators is limited by high capital cost and energy requirements.

Reverse osmosis - This technique may be used to recover nickel solutions and produce high quality rinse water. Its use with chromic acid and other oxidizing acids and with cyanides will have to wait until suitable membranes are perfected. Equipment now in service has not yet reached a high degree of reliability.

Chemical treatment of effluent - Best Practicable Technology - Chemical treatment appears, today, to be the only technology universally applicable to metal finishing effluents. There are probably more than 600 metal finishing processes which are applied in many combinations. They all produce an aqueous effluent which can be chemically treated to reduce the level of metals and other chemicals present in it.

Where nickel, chrome and cyanide could be present in the final effluent, it is necessary to segregate and treat separately the cyanide stream, to avoid the formation of complexes, and the chrome stream, to reduce the metal to its trivalent state. Such segregations must be made before final metal precipitation.

The following steps are, at present, considered to be part of Best Practicable Technology (BPT) for the development of control requirements: segregation and destruction of oxidizable cyanide; segregation and reduction of hexavalent chromium; equalization of the different streams and precipitation of metals; settling of suspended solids; and, separation and disposal of sludges.

Appendix II provides some basic details on cyanide hardening, chrome reduction and metals precipitation.

Metals and other contaminants in the supernatant (and final effluent) are expected to be below or at the levels shown in Table 4.

These values were derived from two references [2] [3] reflecting several years of experience in wastewater treatment and monitoring in Germany and the United States. Appendix III shows the actual limits found in both references for the parameters listed in Table 4.

Other metals, not listed above, will co-precipitate during neutralization.

Additional stream segregation and separate treatment can produce effluents with concentrations of any particular dissolved metal

TABLE 4. EXPECTED LEVELS OF CONTAMINANTS IN FINAL EFFLUENT AFTER CHEMICAL TREATMENT

pH	6 - 9.5	
TSS	20 - 50 mg/l	
	<u>Total (dissolved and undissolved)</u>	<u>Dissolved</u>
Cd	1.5 mg/l	0.2 mg/l
Cr ^{VI}	0.5 "	0.1 "
Cr ^{tot}	1.0 "	0.5 "
Cu	1.0 "	0.5 "
Ni	2.0 "	1.0 "
Pb	1.5 "	0.5 "
Zn	2.0 "	1.0 "
Fe	2.0 "	1.0 "
CN Oxidizable	0.1 "	0.1 "
CN Total	1.0 "	1.0 "

lower than the values shown. Filtration of the final effluent can reduce undissolved metal levels to practically nil.

Fluoride, and phosphate can also be chemically precipitated, while ammonia could be removed by air stripping.

Under special circumstances the values in Table 4 may not be met. However, it is felt that such cases should be analysed on a case by case basis. In general, chemical treatment lends itself to the application of additional methods or steps, when required, to further improve the quality of the effluent before discharge.

Rinses for acid and alkaline surface cleaning, which are pretreatment operations prior to finishing, require large volumes of water. This water is usually mixed, before final neutralization, with the rinses originated from surface finishing operations. However, since pretreatment rinses contain mainly the substrate metal to be plated (and very minor quantities of other metals), they could be segregated and treated separately. The balance of the effluent could be also treated separately and the two streams mixed before discharge. Mixing will reduce the concentrations of metals (and other substances present

in only one of the two streams); the reduction will depend upon the relative volumes of the two streams before mixing.

This technique, while requiring additional segregation and treatment cost, may ensure a final content of dissolved metals much below the values shown in Table 4 and easily in a range non-acutely lethal to fish [5].

It is possible to automate the cyanide oxidation and the chromic acid reduction. When combined with a pH meter-controller, the whole system can be automated. However, the use of automated systems in small companies is questionable both because of the cost and the ability to maintain and supervise the use of them. The most practical approach for small companies would be to reduce water flows so that batch treatment can be used.

While some plating plants will require only chrome treatment, most will require two or more of the above steps. The automatic controls and engineering required are much the same regardless of size of the plant. Tanks, building and ancillary equipment required will be approximately proportional to the volume of the effluent.

2.5 Sludges and Dumps

Sludges are generated in four ways in the metal finishing industry:

- a. filter cleanouts;
- b. bath purification procedures;
- c. burnishing and tumbling barrel discharges; and,
- d. metallic hydroxides from chemical waste treatment processes.

Filter cleanout is usually an off-shift operation performed weekly. Bath purification procedures are carried out to remove contaminants in baths, and frequency is from every two months to once a year. Burnishing and tumbling barrel discharges may be generated daily. Metallic hydroxide sludges are now being generated daily in most treatment plants (nearly all of these in Ontario). One typical medium to large size plant will generate and dispose of up to 3,000 gallons of sludges and spent baths (dumps) per week.

Some municipalities are permitting discharge to their municipal treatment system, but most of the materials are being trucked away for disposal in a manner not always known to the shipper. In occasional isolated instances it has been cheaper to have the material shipped 150 miles to Michigan. The approximate present cost for trucking is 11 cents per gallon. Filter pressing will raise the concentration from less than 2% solids to 30% solids, but the extra capital cost is substantial.

In England, sludges as well as dumps are dealt with according to the local situation. In Birmingham the municipality will pick them up and discharge them to old mine shafts. This practice is under review. A private company has been established there to treat and, where possible, recover materials from these sources. In Nottingham, these materials are trucked to an approved disposal site.

In Germany, in the Ruhr Valley, a central collection and treatment facility has been established by a quasi-government agency (Ruhrverband), which provides the service at a charge for over 200 metal finishing facilities. The capital cost three years ago was \$500,000, approximately half of which was for storage.

In Sweden, centralized facilities will provide for the impoundment of dewatered sludges. Metal hydroxides will be kept alkaline by lime addition and the runoff from the impoundment area will be collected and treated as necessary.

Disposal of dumps and sludges in Canada is still a problem with which control agencies are dealing with various degrees of success. Federal control requirements for the metal finishing industry will increase the amounts of sludges and spent baths generated, and the amounts which cannot be discharged directly or indirectly to receiving waters.

The authors believe that centralized treatment and impoundment facilities represent, today, the most reliable and economical solution. Where not available, sludges and spent baths will have to be handled by each plant to the satisfaction of local, provincial and federal requirements, unless deep well disposal is feasible and permitted.

3. DISCHARGES TO MUNICIPAL SEWERS

3.1 Background

From the survey [1], it has been estimated that metal finishing plants discharge wastewaters to municipal sewers in the following percentages:

Atlantic Provinces	75%
Quebec	60%
Ontario	70%
Manitoba, Saskatchewan, Alberta	45%
British Columbia	50%

The percentages of discharges to receiving waters would considerably increase if the number of municipal treatment plants in existence and/or the effectiveness of these plants were taken into consideration. It is obvious that the only difference between direct discharges to receiving waters and discharges to sewers not provided with treatment is the ownership and the jurisdiction over the pipe leading to the receiving waters. Given the percentage of companies discharging to municipal sewers, and the relative effectiveness of the primary and secondary treatments already in place, it is clear that an effective control of metal finishing waste must include requirements for discharges to municipal sewers.

There are three main aspects to be considered: the legislative authority over the discharges themselves; the degree of removal of heavy metals and other deleterious substances by municipal treatment plants; and, federal control requirements (under the Fisheries Act) in the context of existing Provincial-Municipal agreements, policies, enforcement of existing bylaws and future programs.

3.2 Legislative Authority

The Fisheries Act (Section 33(2)) prohibits anyone from permitting the deposit of a deleterious substance in any place such that the deleterious substance may enter any water frequented by fish. This interpretation, as it would apply to discharges to municipal sewers, has been formally confirmed by the Federal Department of Justice, and an expression of this policy has been incorporated in the Petroleum Refinery Regulations.

3.3 Effectiveness of Municipal Treatment Plants in Removing Metal Finishing Waste

The indiscriminate discharge of untreated metal finishing waste may result in hazards such as harm to the sewer system, danger to the employees in the sanitary department, and interference with the proper operation of biological processes used by the sewage treatment plant. An additional problem is represented by the metallic contamination of sludge, which will increase metal concentrations in the soil in agricultural areas where the sludge is used as fertilizer. Metals can also accumulate and concentrate in sludge digestors, resulting in decreased gas production.

Existing municipal bylaws reflect these hazards, although they vary from town to town as different factors influence them. The most important factor has been the expected dilution of the waste before reaching the sewage plant.

Historically, sewer bylaws have been designed to protect sewers and treatment facilities, not to protect fish in waters receiving the municipal effluent. However, it has been noted that aerobic bacteria can be acclimatized to cyanide and biodegrade it, though the presence of metals such as copper will interfere with the acclimatization process. Suspended solids and insoluble metal hydroxides will also be retained and concentrated with the sludges, while dissolved metals will be only partially precipitated because of various complexing agents present and because the pH of the biological system is too low for efficient metal removal. Metals not retained in the municipal sludge will be discharged with the effluent to receiving waters.

The effectiveness of municipal sewage treatment plants in the removal of metal finishing wastes has been investigated by several researchers [4] [6] [7]. It is influenced by several factors, including the characteristics of the effluent, its interactions with the municipal sewage and the type of sewage treatment process. Generally, it can be stated that a sewage treatment plant has a limited ability to treat the wastes found in metal finishing plant effluents. Its effectiveness may be high for the organic materials and much lower for the metals dissolved in the effluent.

Any judgement of the effectiveness of any sewage treatment plant in the removal of metal finishing wastes should be based on an analysis of the wastes and on the unique technological capabilities of the sewage treatment plant.

In addition, when considering the adequacy of municipal treatment plants as off-site treatment, one should also remember that, occasionally, in order to prevent accidental discharges from reaching the sewers, temporary by-pass of such discharges into storm sewers has been practiced both in Canada and abroad.

3.4 Control of Effluents Discharged into Municipal Systems or Other Off-site Treatment Facilities

Concern has been expressed over the practicability of enforcement and the current practice in some Provinces of delegating to the municipalities responsibility for both regulating and enforcing aspects of controlling discharges to sewer systems.

Concerns have been expressed by some Provinces over the possible "interference" of federal legislation with the present "modus operandi" in effect between them and the municipalities.

Concern over "equity" has also been expressed by industry, relating to the different degree of enforcement of bylaws exercised by different municipalities. Apparently, the desire to either attract or discourage the establishment of new metal finishing plants is reflected in the severity of the enforcement of bylaws, when they exist. The failure to regulate discharges to municipalities will encourage the establishment of new plants in locations where bylaws are less stringent or loosely enforced.

A statement will be inserted in the future metal finishing requirements providing an exemption where, prior to being deposited, liquid effluent has been treated in such a manner as the Minister may approve in writing, at a site outside a plant for the purpose of removing therefrom the deleterious substance prescribed in the Regulations. This statement will apply to effluent discharges into municipal systems or other off-site treatment facilities such as, for instance, centralized treatment plants.

The responsibility centre for the approval required for such off-site discharges will normally rest with the agency charged with the control requirements.

It is foreseen that an industry, in order to receive approval, will have to submit a formal request including substantiating data showing that the liquid effluent from its plant will receive equivalent treatment prior to ultimate discharge. Such a request should contain detailed information and a schedule of compliance for any in-plant modifications that are planned so that the treatment will be essentially equivalent. In assessing an application for an existing industry, consideration may be given to future installation of municipal treatment systems if these installations can be verified and the construction time frame is adequate.

If a Province or Municipality has, or develops and enforces, a comprehensive sewer bylaw for industrial discharges, and the sewage treatment plant is technologically capable of providing treatment equivalent to BPT, industries in this jurisdiction may look forward to almost automatic approval when the intent with the bylaw has been essentially achieved.

Where a municipal sewage treatment plant can provide only part of the treatment required, the industry could be required to provide complementary effluent treatment to ensure equivalence to BPT.

4. ECONOMIC ASPECTS

4.1 Capital and Operating Costs of Wastewater Treatment

Reference was made in Section 2 to the various steps considered to be Best Practicable Technology for effluent control requirements.

An accurate analysis of capital and operating costs is difficult because of the variation of processes and conditions within the industry. Further, there is a lack of detailed information on numerous plants. Given these qualifications, an estimate of costs to industry was attempted considering the size of the facilities and the variations of treatment which may be required for facilities of the same size. Such costs were arrived at by analyzing the information available on more than 70 companies estimated to represent the geographical distribution, combinations of processes, and sales volumes of the segment of the industry under consideration. Only non-captive operations were selected. It was felt that captive operations, for which it was difficult to isolate meaningful sales volumes, could afford treatment facilities or had the option of sub-contracting their metal finishing work. More than 50% of the operations responding to the survey were captive.

Estimated capital and operating costs for applying Best Practicable Technology (which includes good housekeeping) are shown in Figure 1. Details are given in Appendix IV. For the same sales, the top of the range represents companies with complex operations and requiring most or all the steps indicated as Best Practicable Technology. The figure takes into consideration the fact that some wastewater treatment equipment is already in place.

In general, the cost of applying BPT is estimated to be from \$15,000 to \$100,000 or more, depending upon size and complexity of processes. Smaller plants are estimated to be in the \$15,000 to \$40,000 range.

From the point of view of initial investment, it is estimated that the application of BPT will require from 20 to 40 percent additional capital, depending upon size and complexity. The percentage can be much higher for small operations.

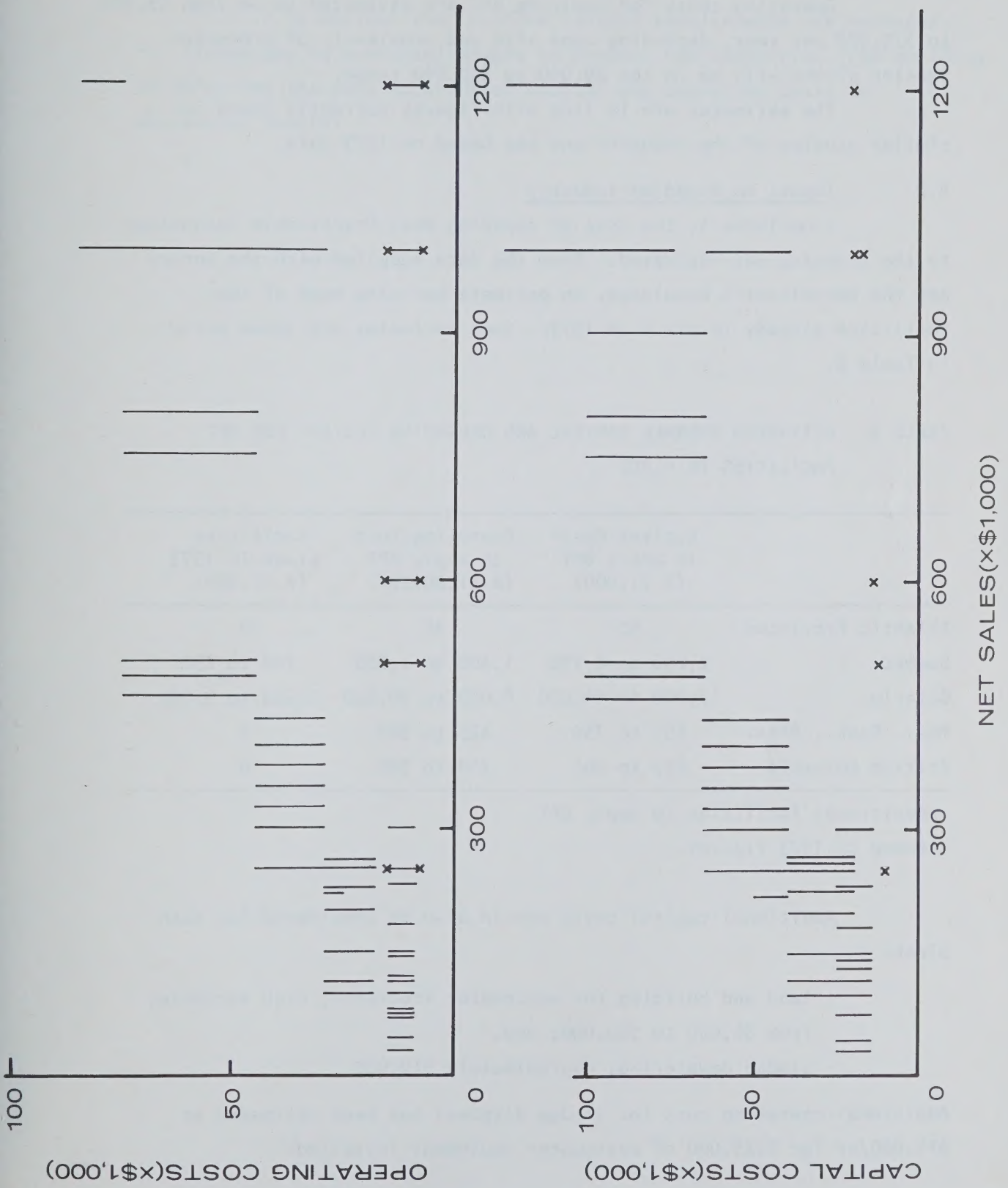


FIGURE 1. WASTEWATER TREATMENT COSTS vs. NET SALES
(NON-CAPTIVE OPERATIONS; BASED ON 1973 DATA)

Operating costs for applying BPT are estimated to be from \$9,000 to \$75,000 per year, depending upon size and complexity of processes. Smaller plants will be in the \$9,000 to \$30,000 range.

The estimates are in line with figures currently found in similar studies of the industry and are based on 1973 data.

4.2 Impact on Canadian Industry

From Table 1, the cost of applying Best Practicable Technology to the industry was estimated. From the data supplied with the survey and the consultant's knowledge, an estimate was also made of the facilities already in place in 1973. Such estimates are shown below in Table 5.

TABLE 5. ESTIMATED OVERALL CAPITAL AND OPERATING COSTS** FOR BPT - FACILITIES IN PLACE

	Capital Cost* to apply BPT (X \$1,000)	Operating Cost to apply BPT (X \$1,000/yr)	Facilities place in 1973 (X \$1,000)
Atlantic Provinces	50	35	0
Quebec	2,250 to 2,750	1,400 to 1,800	200 to 250
Ontario	12,000 to 14,000	8,000 to 10,000	2,500 to 3,000
Man., Sask., Alta.	650 to 750	425 to 500	0
British Columbia	425 to 500	250 to 300	0

*Additional facilities to apply BPT

**Based on 1973 figures.

Additional capital costs should also be considered for each plant:

- land and building for wastewater treatment, high variable, from \$4,000 to \$30,000; and,
- sludge dewatering, approximately \$10,000.

Additional operating cost for sludge disposal has been estimated at \$14,000/yr for \$125,000 of wastewater equipment installed.

It is obvious that uniform control requirements are necessary for discharges to municipal sewers to prevent new industries from avoiding or deferring the very substantial capital and operating costs for wastewater control.

5. OPTIONS FOR WASTEWATER CONTROL

The following are, basically, the options available for the control of effluents discharged from the metal finishing industry:

1. Ignore all discharges from this industry. This option will not be considered in this report.
2. Prepare requirements based on the assimilative capacity of the receiving waters. Because of the refractory or persistent nature of metal wastes, this option is contrary to the present policies of Environment Canada.
3. Prepare requirements based only on concentrations for each control parameter in the final effluent. This approach, widely adopted in Canada and abroad [1], would be adequate if off-shift discharges could be prevented through continuous monitoring of the effluent. However, monitoring with a monthly frequency is closer to the limit for the majority of small platers and off-shift discharges could indeed occur.
4. Prepare requirements explicitly addressed to the sources of each discharge. These could:
 - prohibit the dumping of sludges and concentrated solutions;
 - request the application of good housekeeping procedures to prevent and contain spillages, leaks, etc.; and,
 - limit each control parameter by specifying its maximum concentration in the final effluent.

The implementation of this option would require a combination of regulations, guidelines and codes of practice, and a sludge disposal option.

5. Prepare requirements expressing allowable discharges of control parameters as quantities proportional to the production rate of a plant. Because of the difficulties in relating pollution losses to production units, this approach is considered impractical.

The combination of regulations, guidelines and codes of practice outlined as option 4 would provide a very substantial pollution roll-back.

The package, based on Best Practicable Technology, should be complemented by adequate reporting procedures, such as an obligation to report in writing the means of disposal of sludges and other concentrated solutions, in order to provide a strong incentive against off-shift dumping procedures.

To maintain equity, both discharges to receiving waters and municipal sewers should be subject to control requirements.

Once segregated and contained, sludges and concentrated solutions must be disposed of. Practical treatment and disposal technology is available abroad, and Canadian industry, provincial agencies and large municipalities should be exposed to it in order to plan its application wherever possible.

The promulgation, today, of a law explicitly prohibiting the discharge of sludges and concentrated solutions may create a difficult situation in those locations where sludges and concentrated solutions could not be satisfactorily disposed of because of lack of adequate facilities. It may be necessary, for a period to be established, that both existing and new plants have effluent requirements expressed as objectives, while reporting procedures could be legal requirements for new plants. Such objectives could be changed into legal requirements after municipalities and provinces have had the time to consider and plan adequate disposal facilities.

It should be noted that it may not be practical today to achieve a non-acutely lethal effluent. However, the reduction in pollution load from the enforcement of the controls suggested would be very significant. The authors believe that, while efforts should be continued towards non-acutely lethal effluents, the suggested controls would generate an effluent of relatively minor significance, considering that, in almost all instances, treated effluents will be greatly diluted in receiving waters.

It should be also noted that, in general, metal finishing operations tend to be captive of other industries. In the segment of the industry under consideration, more than 50% of the responses were from captive operations. This fact poses two main problems: the first is related to economic considerations; the second is related to the

practical difficulties that may arise in defining, for legal purposes, metal finishing operations which are captive. Such difficulties are not completely clear at the present moment.

REFERENCES

1. "Review of the Canadian Metal Finishing Industry - Consumption of raw materials and options for water pollution control", Water Pollution Control Directorate, Environmental Protection Service, Environment Canada, Report No. EPS 3-WP-75-2, March 1975.
2. "Normalwerte für Abwasserreinigungsverfahren" (Standard Values for Wastewater Purification Procedures), 2. erweiterte und überarbeitete Auflage, Sonderdruck der Länderarbeitsgemeinschaft Wasser, LAWA, 1970.
3. "Effluent Limitation Guidance for The Refuse Act Program, Metal Finishing Industry", U.S. Environmental Protection Agency, September, 1972.
4. Oliver, B.G. and E.G. Cosgrove, "The Efficiency of Heavy Metal Removal by a Conventional Activated Sludge Treatment Plant", Water and Wastewater Treatment Research, Canada Centre for Inland Waters, Environment Canada, Burlington, n.d.
5. Buffa, L., "A Modification of the Traditional Sequence for the Treatment of Wastewater from Metal Finishing Installations", Water Pollution Control Directorate, Environmental Protection Service, Environment Canada, Report No. EPS 3-WP-76-6, 1976.
6. Tarvin, D., "Metal Plating Wastes and Sewage Treatment", paper presented at the Annual Meeting of the Ohio Sewage and Industrial Waste Treatment Conference, Cleveland, Ohio, June 13, 1956.
7. Lancy, L.E., "The Effects of Metal Finishing Effluent on the Sanitary Sewage Treatment Processes and Sewer Structures", paper presented at the 49th Annual Technical Proceedings of the American Electroplaters Society, 1962.

APPENDICES

APPENDIX I

EXAMPLES OF CAPITAL COST OF RECOVERY SYSTEMS, 1973

Recovery System	Chemical Recovered	Approximate Cost	Capital Cost Recovery*
Ion Exchange	Nickel Sulphate 15,000 lb/yr	\$12,000.00	2½ years
Ion Exchange	Cadmium Acid 30,000 lb/yr	\$21,000.00	1 year
Evaporator	Chromic Acid 40,000 lb/yr	\$90,000.00	4 years
Evaporator	Nickel Sulphate 25,000 lb/yr	\$80,000.00	3 years
Reverse Osmosis	Nickel Sulphate 18,000 lb/yr	\$15,000.00	2 years

*Note: These are manufacturer's estimates and subject to wide fluctuation in practice.

APPENDIX II

MAIN STEPS IN CHEMICAL TREATMENT

Cyanide Destruction - Oxidation by alkaline chlorination is almost universally used and is relatively simple. pH is raised to 11.0 and sufficient chlorine is added to complete the oxidation to CO_2 and N_2 . 4.5 lb of chlorine is required to oxidize 1 lb of cyanide. If iron or nickel are present, they will complex the cyanide and greatly increase the time of oxidation.

Chromium Reduction - Since most of the chromium is in the hexavalent state it is necessary to reduce it to the trivalent form by adding a reducing agent (SO_2 , sodium metabisulphite) at a pH of 3.0. With vigorous agitation the reaction is very fast.

Metals Precipitation - Several factors influence the degree to which each metal will be precipitated and removed from the effluent. Such factors include precipitation time, initial concentration (and relative ratios) of metal ions present, the reagent used and the presence of chelating agents which may block the precipitation itself.

In general, the pH of minimum solubility for each metal will vary with the total chemical content of the given waste. To achieve optimum precipitation for any one metal, it may be necessary to segregate the stream containing it and treat it separately. However, a pH of 8.5 is usually a satisfactory compromise for the metals most commonly found in plating plants. When pH is raised to this level and vigorous mixing is applied, the metal hydroxides precipitate. The resulting sludge can be concentrated, after several hours of settling, to approximately 2% solids.

While a pH of 8.5 may be a good compromise in most cases, the residual levels of nickel may still be high and a further increase in pH may be required.

APPENDIX III

EXAMPLES OF EFFLUENT STANDARDS FOR THE METAL FINISHING INDUSTRY (control parameters considered in this report)

CONTROL PARAMETERS	EFFLUENT LIMITATION GUIDANCE*				STANDARD VALUES TO WATER PURIFICATION PROCEDURES**
	New Plants		Existing Plants		
	Dissolved	Total***	Dissolved	Total***	
pH					6.5-9.0
TSS (mg/l)		6-8.5 10		6-8.5 50	
Cd (mg/l)	.1	1.1	.2	1.2	3.0
Cr ^{vl}	.05	---	.1	---	.5
Cr ^{tot}	---	.25	---	.5	2.0
Cu	.2	1.2	.5	1.5	1.0
Ni	1.0	2.0	2.0	3.0	3.0
Pb	.05	1.05	.1	1.1	---
Zn	.5	1.5	1.0	2.0	3.0
Fe	.5	1.5	1.0	2.0	2.0
CN oxidizable	.03	---	.1	---	.1
CN total	.53	---	1.1	---	---

*Effluent Limitation Guidance for the Refer Act Program - Metal Finishing Industry - September 1972. Limits achievable by chemical treatment. Approach later abandoned by the U.S. Environmental Protection Agency.

**Normalwerte fur Abwasserreinigungsverfahren - 1970. Limits achievable by cyanide oxidation, chromate reduction, neutralization and removal of precipitated salts.

***Dissolved and undissolved.

APPENDIX IV

BACKGROUND FOR COSTS ESTIMATES

The following assumptions have been made in estimating costs ranges for wastewater treatment:

a) Capital Cost

1. pH adjustment - from \$6,000 (batch) to \$30,000 (continuous automatic).
2. Cr reduction - from \$5,000 (batch) to \$30,000 (continuous automatic).
3. CN destruction - from \$5,000 (batch) to \$25,000 (continuous automatic).
4. Clarification - from \$5,000 (batch) to \$50,000 (continuous automatic).

b) Operating Cost

- Estimated replacement value of metal finishing installation at 50% of net annual sales.
- 10 years depreciation.
- 8% interest on capital.
- From 0.5 to 2.0 man years labour, depending upon size and complexity of plant.
- Chemicals from 5% to 20% of total operating cost.
- Services from 10% to 25% of total operating cost.

Date Due	
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Publishing Body	EPS 3-WP-76-10
Wastewater sludge control	
Title	in The Canadian metal
finishing industry	
BROWERS NAME	DATE RET'D

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